Fermilab

TM-775
2212.200

TESTS OF CHANGES IN THE HORIZONTAL PRODUCTION ANGLES IN THE MESON LABORATORY

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The Meson Department has installed a system of three magnets that allow large changes in the horizontal production angle of the six secondary beams. The installation took place in September, together with magnets that allow change in the vertical production angles as well.[1] The three magnets change the horizontal angle of the proton beam striking the Meson Area target without affecting the position of the beam at the center of the target (see Figures 1 & 2). The net angle of the system at the target is equivalent to that produced by one ten-foot external proton beam (EPB) dipole[2] and is illustrated in Figure 3 for a 400 GeV energy proton beam. This report describes the initial test of the system.

The production angles and acceptances for the secondary beams are shown in Table 1. The apertures in the fixed collimators on the Meson target load were designed using these acceptances. The horizontal steering system has the capability to reduce the horizontal production angle for either the M1 or M6 secondary beams to zero. By using both horizontal and vertical steering magnets the M1 and M6 production angles can be reduced to 0.2 milliradians. In actual use, choices of horizontal and vertical steering values will depend on the experiments using the beams. During the initial test described here, the following situation existed.

	EPB	M1 Beam	M2 Beam	M6 Beam
Momentum (GeV/c)	400	200	200	100
Polarity	+	+	+	-

There was no vertical steering during the test; thus, the vertical production angle was 0.7 milliradians. The target was beryllium, 0.062 inches square by 8 inches long.

The test was done by sweeping the current in the horizontal steering magnets from 0 to 1762 amperes with a polarity such that the M1 production angle was decreased, and then sweeping it from 0 to 1290 amperes with the opposite polarity. The experimental groups using the M1 and M6 beam lines recorded relative changes in beam flux (normalized by the secondary emission monitor of the incident proton beam), and changes in particle composition of the two beams. Data from beams other than M1 and M6 were not recorded during this test. The results are presented in Tables 3 and 4 and in Figures 4 through 7.

The M1 flux went up a factor of 4.5 and the M6 flux dropped a factor of 2.4 in one direction[3]; in the opposite direction the M1 flux dropped by a factor of more than 10 and the M6 flux increased by 64%. Particle composition in M1 changed from 17% π^+/total to 21% π^+/total as the production angle was decreased. The ratios $\overline{P}/\pi^-$ and K^-/π^- changed from 1.6% and 4.4% to 2.2% and 4.8% when the M6 production angle was increased. No dramatic effect was seen when the proton beam entered the M1 or M6 collimator apertures.

Summary

The angle varying bends on the target load worked successfully. Changing the horizontal production angle for the M1 beam at 200 GeV positives and the M6 beam at 100 GeV negatives for 400 GeV protons on target produced in this test a dynamic range of >45 in M1 flux and a dynamic range of 4 in M6 flux. The minority components in a negative 100 GeV/c beam had a dynamic range of less than 1.7 (relative to the π^- flux) over the full sweep in horizontal production angle.

REFERENCES

[1] H. F. Haggerty, "Meson Vertical Targetting Study", TM-750 October, 1977.

[2] T. E. Toohig, "Fermilab Magnets, Power Supplies, and Auxiliary Devices", TM-632, December, 1975.

[3] By referring to the Hagedorn-Ranft curves in FN-216 by Awschalom and Van Ginnekin we would expect a change of a factor of 10 in π^+ yield in going from 3.5 to 0 milliradians for 200 GeV secondaries from 400 GeV protons incident on beryllium. For protons the corresponding factor is 7.1. If one starts at 17% π^+/total at 3.5 mr, these numbers suggest 22.4% π^+/total at 0 mr. Naive application of the formula of C. L. Wang, Physical Review D10, 3876 (1974), would lead one to expect a factor of 13.1 in going from a production angle of 3.4 mr to 0.7 mr for π^+ production.

TABLE CAPTIONS

1. Shown are the angles of the beam axis for each beam in the Meson coordinate system, and the acceptances used to design the target load collimators in 1973. The direction of the external proton beam is shown in the same coordinate system.

2. Shown are the values of the current used to excite the horizontal angle varying bends, the corresponding net values of ∫Bdl, the horizontal bend angle at the target for a 400 GeV/c proton beam, and the corresponding production angles for M1 and M6. The sign of the current indicates the state of the polarity bit for the controlling name, TGTAI, on the Meson control computer system.

3. The data taken by Experiment 61 for the M1 beam at 200+ while varying the horizontal production angle. The data have been manipulated appropriately for Figures 4-7.

4. The data taken by Experiment 396 for the M6 beam at 100-.

FIGURE CAPTIONS

1. A schematic showing location and relative bend angle of the angle varying magnets. Distances are indicated in feet and are to the magnet centers.

2. A sketch of positions and horizontal apertures for the horizontal angle varying bends and the collimators downstream of the target. A brass insert was used in the magnet closest to the target; its aperture is 0.4 inch vertical by 1.1 inch horizontal.

3. This figure shows the relationship between current and horizontal angle at the target. Since the net bend is that of one 10-foot EPB dipole, this curve is identical to that for the angle produced by a 10-foot EPB dipole.

4. (Relative yield/# incident protons) for M1 and M6 vs horizontal targetting angle. The horizontal scale for angle is non-linear; that shown for horizontal bend current is linear.

5. (Relative yield/# incident protons) for M1 and M6 vs production angle of each beam.

6. (Relative yield/# incident protons) for M1 and M6 vs the square of the production angle for each beam.

7. Figure 7 shows the change in the particle contents for M1 and M6 as the horizontal targetting angle is varied. The horizontal scale for angle is non-linear; that shown for horizontal bend current is linear.

TABLE I

Production Angle and Angular Acceptances
Meson Secondary Beams (1973)

Beam	θ_h Horizontal (mr)	θ_v Vertical (mr)	$\Delta\theta_h$ (mr)	$\Delta\theta_v$ (mr)
M2	0.0	0.00	±0.42	±0.20
M4	0.0	-8.25	±0.30	±0.15
M1	- 3.0	0.00	+0.00* -0.70	±2.30*
M6	+ 2.5	0.00	±0.80	±0.80
M5	+15.0	0.00	±0.75	±1.23
M7	-25.0	0.00	±0.33	±0.76

External proton beam direction in same system of coordinates

	θ_h	θ_v	Comment
EPB 1)	0.0 mr	-1.75 mr	Initial (1973)
EPB 2)	0.0 mr	-0.70 mr	At present, with no excitation in vertical angle varying magnets

θ_h = horizontal angle in x-z plane
θ_v = vertical angle in x-z plane

*Shown are 1973 values. At present M1 has the following acceptances:

	$\Delta\theta_h$	$\Delta\theta_v$
$p \leq 250$	+0.00 -0.70	±1.4
$250 \leq p \leq 400$	+0.00 -0.50	±0.6

See TM-751 for further information on current acceptances of each beam.

TABLE II

TGTAI current	Equivalent $\int Bdl$ kG-M	θ_h Bend Angle At 400 GeV/c (mr)	M6 Production Angle $\sqrt{(2.5-\theta_h)^2+0.7^2}$	M1 Production Angle $\sqrt{(\theta_h+3.35)^2+0.7^2}$
off	0	0	2.60	3.42
- 240	7.632	- .57	3.15	2.87
- 410	13.110	- .98	3.55	2.47
- 575	18.560	-1.40	3.96	2.07
- 690	21.980	-1.65	4.21	1.84
- 900	28.540	-2.14	4.69	1.40
- 995	31.830	-2.38	4.93	1.20
-1092	34.780	-2.61	5.16	1.02
-1160	36.590	-2.74	5.29	0.93
-1296	39.590	-2.97	5.51	0.80
-1482	42.970	-3.22	5.76	0.71
-1762	47.250	-3.54	6.08	0.72
off	0	0	2.50	3.42
410	13.11	0.98	1.67	4.39
578	18.56	1.40	1.30	4.80
686	21.98	1.65	1.10	5.05
894	28.54	2.14	0.79	5.53
1092	34.78	2.61	0.71	6.00
1290	39.59	2.97	0.84	6.36

EXPERIMENT 61 RESULTS - HORIZONTAL STEERING
M1, 200 GeV/c, POSITIVE

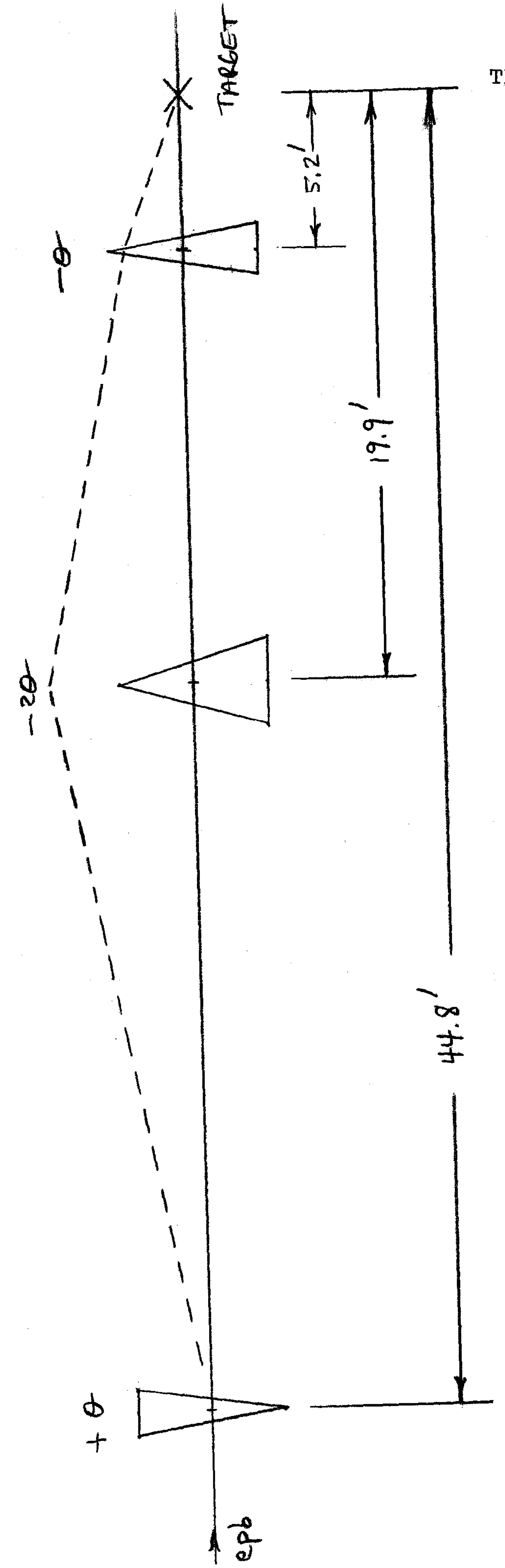
TGTAI	θ_h	SEM	T4	S4C5·C	S4C5	T4/SEM	$\frac{S4C5\cdot C}{S4C5}$	$\frac{S4C5\cdot C}{S4C5}$	Production Angle
current (amps)		3 pulses ÷ 109	÷ 1000	x 1000	x 1000	relative	x 100	normalized	$\sqrt{(\theta_h+3.35)^2+(0.7)^2}$
off	0	1402	145.5	14.16	82.1	1.00	17.2	1.000	3.42
off	0	1235	134.8	12.89	76.4	1.00	16.9	.982	3.42
- 240	- .57	1324	204.6	19.19	111.0	1.45	17.3	1.000	2.87
- 410	- .98	1371	279.5	25.90	143.9	1.92	18.0	1.046	2.47
- 576	-1.40	1482	400.7	35.20	190.2	2.54	18.5	1.075	2.07
- 690	-1.65	1442	430.0	39.10	202.4	2.81	19.3	1.122	1.84
- 897	-2.14	1357	530.9	47.30	232.8	3.68	20.3	1.180	1.40
- 995	-2.38	1812	722.2	59.30	289.1	3.75	20.5	1.192	1.20
-1092	-2.61	967	399.0	39.50	188.0	3.88	21.0	1.221	1.02
-1160	-2.74	1627	734.4	63.10	300.0	4.25	21.0	1.221	0.93
-1292	-2.97	1526	689.0	59.70	283.0	4.25	21.1	1.227	0.80
-1482	-3.22	1724	795.1	64.20	307.9	4.34	20.8	1.209	0.71
-1762	-3.54	1669	790.7	61.00	294.7	4.46	20.7	1.203	0.72
off	0	1592	165.0	15.70	92.2	1.00	17.0	1.000	3.42
+ 410	0.98	1535	78.9	8.56	48.3	.50	17.7	1.041	4.39
+ 895	2.14	735	10.3	1.03	5.68	.13	18.1	1.065	5.53
+1092	2.61	941	8.3	.83	4.62	.08	18.0	1.059	6.00

Table III

EXPERIMENT 396 RESULTS - HORIZONTAL STEERING
M6, 100 GeV/c, NEGATIVE

TGTAI current (amps)	θ_h	SEM $\div 10^9$	Beam $\div$ 1000	π^-	K^- Fractions x 100	$\bar{P}$ x 100	Beam/SEM normalized	K^-/π^- normalized	$\bar{P}/\pi^-$	Production Angle (mr)
off	0	457	477	.927	4.10	1.50		1.000	1.000	2.60
- 240	- .57	552	475	.923	4.18	1.66	.824	1.024	1.111	3.15
- 410	- .98	470	389	.923	4.20	1.70	.793	1.029	1.138	3.55
- 575	-1.40	445	332	.923	4.18	1.75	.715	1.024	1.172	3.96
- 690	-1.65	455	343	.921	4.30	1.80	.722	1.056	1.208	4.21
- 900	-2.14	427	283	.921	4.30	1.85	.635	1.056	1.241	4.69
- 995	-2.38	600	331	.920	4.30	1.80	.528	1.057	1.209	4.93
-1092	-2.61	305	152	.918	4.30	1.80	.477	1.059	1.212	5.16
-1160	-2.74	515	275	.918	4.23	1.87	.511	1.042	1.259	5.29
-1296	-2.97	502	242	.916	4.37	1.88	.462	1.078	1.268	5.51
-1482	-3.22	612	260	.913	4.46	1.95	.407	1.104	1.320	5.76
-1762	-3.54	502	217	.913	4.40	2.00	.414	1.090	1.354	6.08
off	0	657	717	.930	4.10	1.50	1.045	0.997	.997	2.60
410	0.98	470	708	.932	3.80	1.30	1.443	0.921	.862	1.67
894	2.14	215	348	.937	3.50	1.30	1.551	0.844	.857	0.79
1092	2.61	297	442	.937	3.50	1.30	1.426	0.844	.857	0.71
Collimator Openings Smaller										
off		482	137	.930	3.80	1.60	1.000		1.000	2.60
410	0.98	422	156				1.300			1.67
578	1.40	260	115				1.560			1.30
686	1.65	405	188	.934	3.50	1.34	1.630	0.917	.834	1.10
894	2.14	387	147	.930	3.50	1.40	1.340	0.921	.875	0.79
1092	2.61	402	154	.935	3.60	1.40	1.350	0.942	.870	0.71
1290	2.97	505	189	.938	3.40	1.30	1.320	0.887	.805	0.84

Table IV



ANGLE VARYING BENDS
MESON
Figure 1

NATIONAL ACCELERATOR LABORATORY

ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE
MESON			

SUBJECT: MESON TARGETTING — HORIZONTAL

NAME: WEHMANN

DATE: 3/28/77

REVISION DATE:

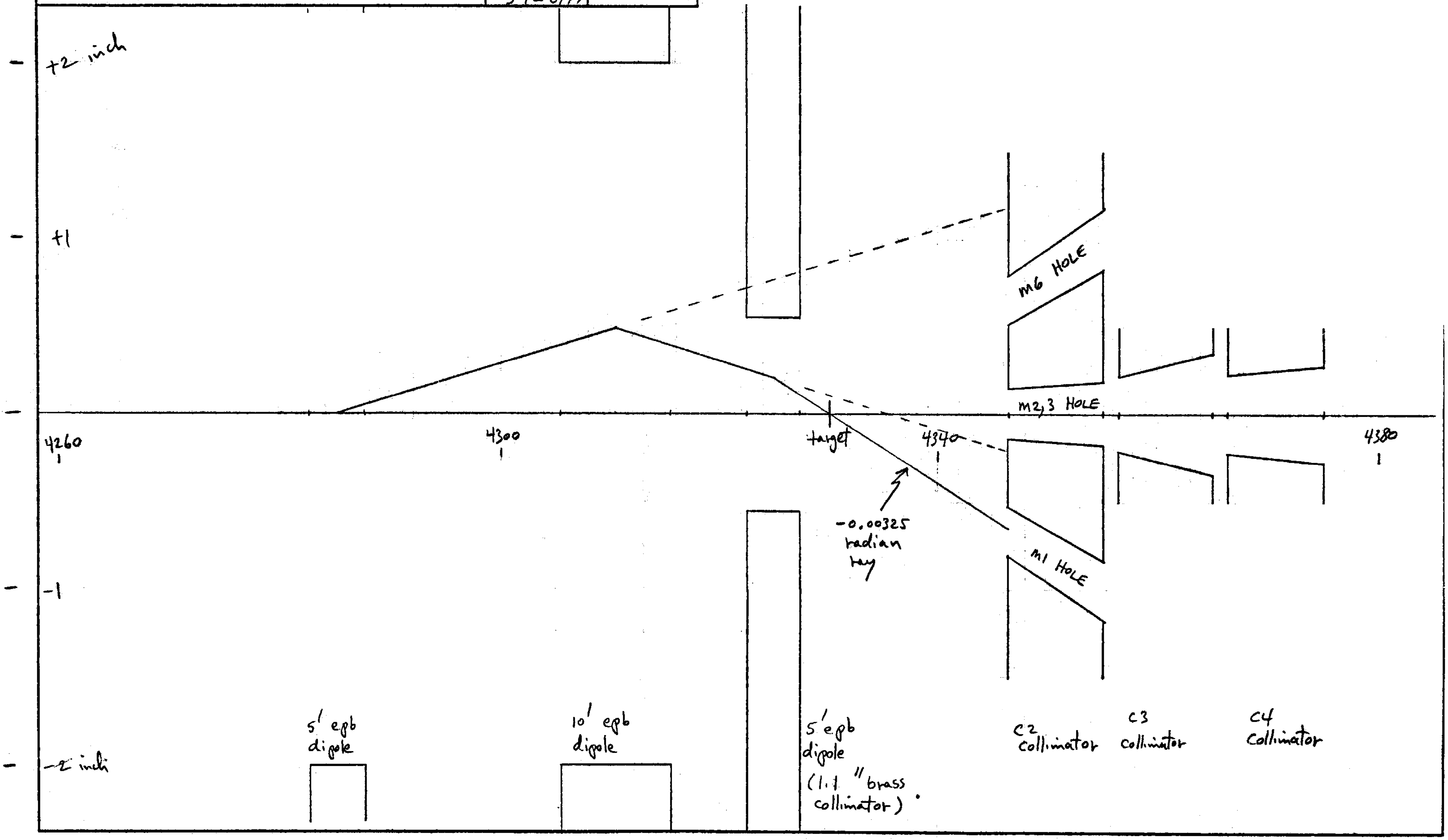
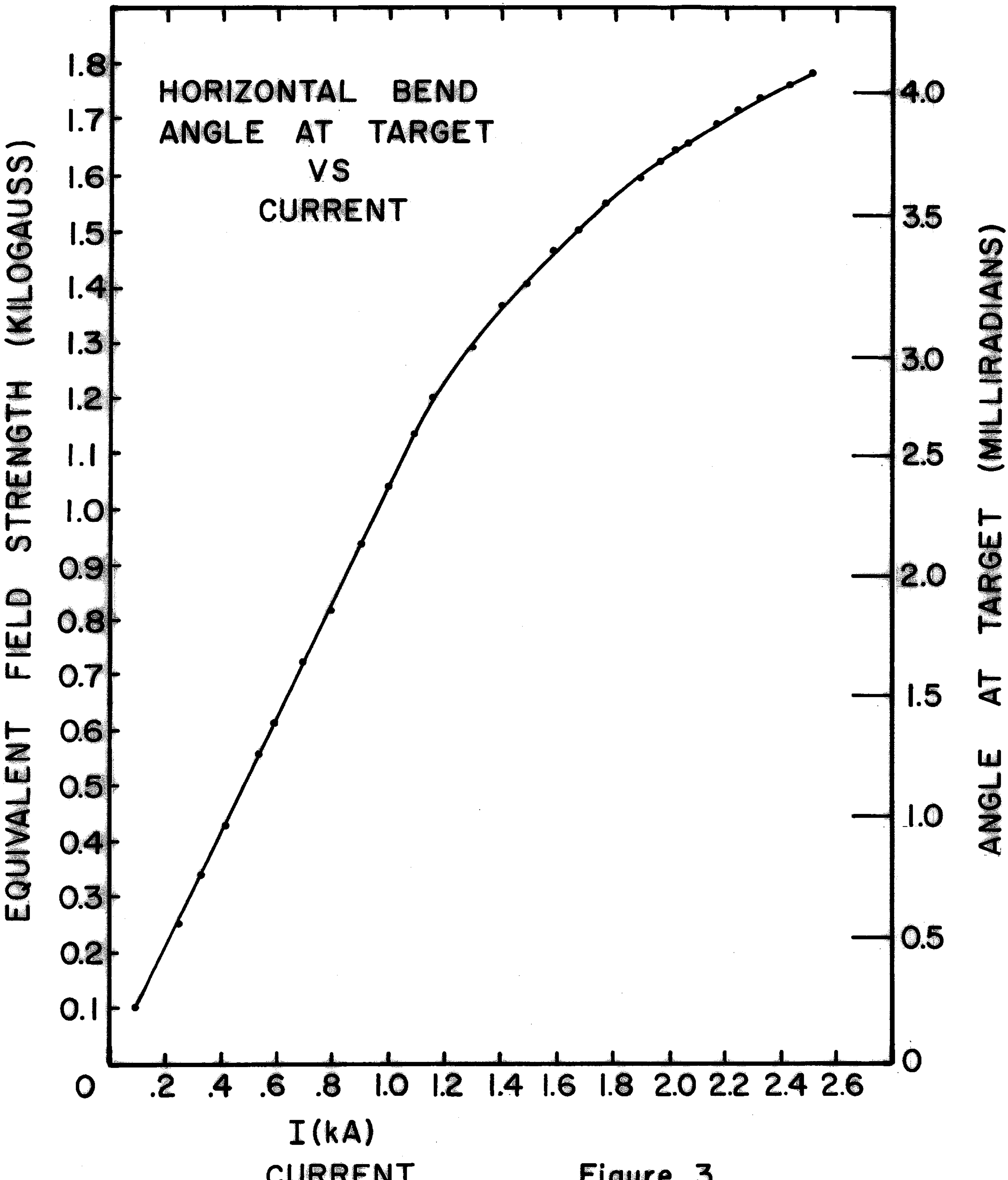


FIGURE 2


HORIZONTAL BEND
ANGLE AT TARGET
VS
CURRENT
EQUIVALENT FIELD STRENGTH (KILOGAUSS)
ANGLE AT TARGET (MILLIRADIANS)
I(kA)
CURRENT
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
0.5
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1.5
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2.5
3.0
3.5
4.0

Figure 3

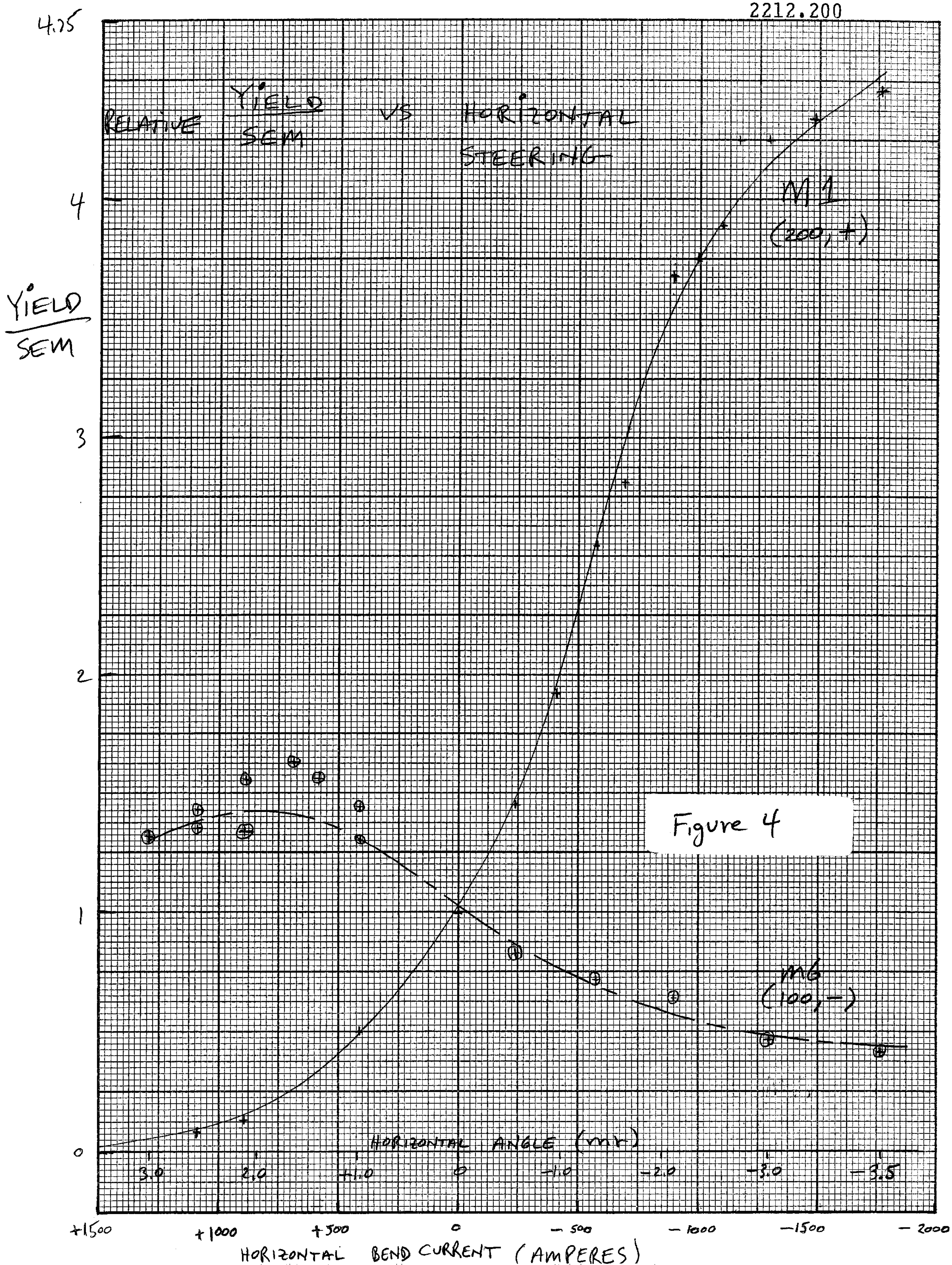
RELATIVE YIELD/SEM VS HORIZONTAL STEERING
4.25
4
3
2
1
0
YIELD/SEM
M1
(200, +)
M6
(100, −)
HORIZONTAL ANGLE (mr)
3.0
2.0
+1.0
0
−1.0
−2.0
−3.0
−3.5
+1500
+1000
+500
0
−500
−1000
−1500
−2000
HORIZONTAL BEND CURRENT (AMPERES)

Figure 4

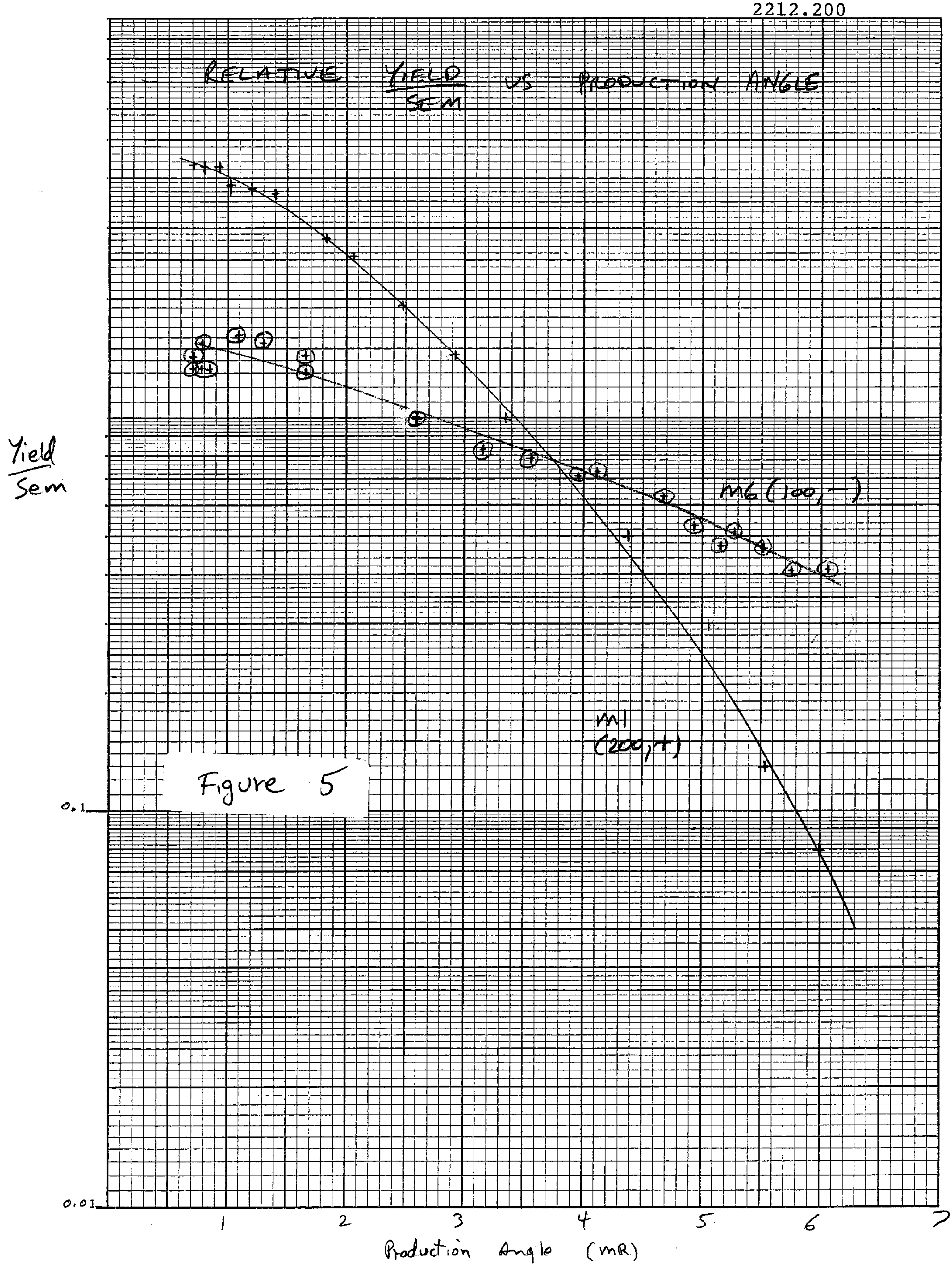
RELATIVE YIELD/SEM VS PRODUCTION ANGLE
Yield/Sem
M6 (100,−)
M1 (200,+)
0.1
0.01
1
2
3
4
5
6
7
Production Angle (MR)

Figure 5

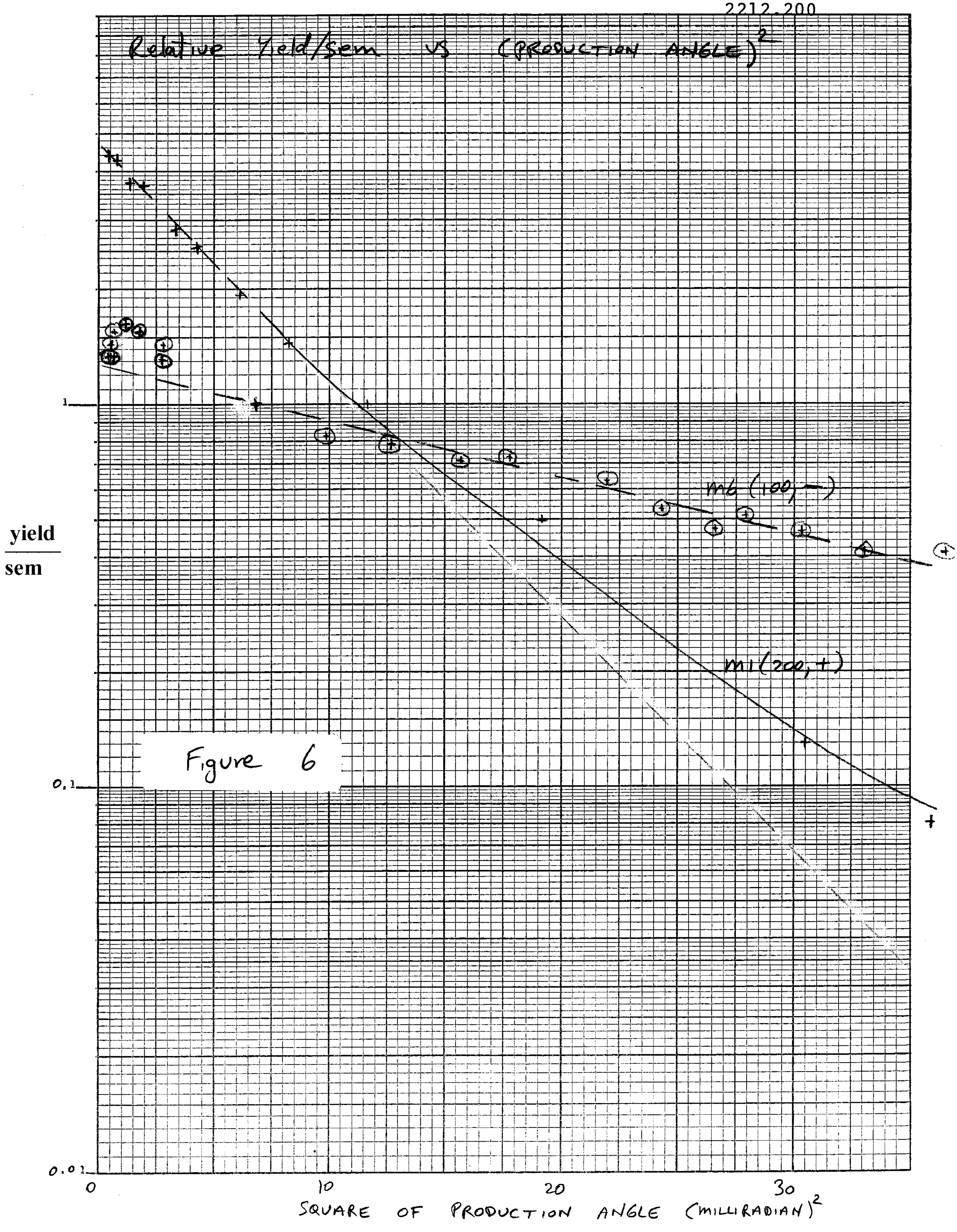
Relative Yield/sem vs (PRODUCTION ANGLE)^2
yield / sem
1
0.1
0.01
0
10
20
30
SQUARE OF PRODUCTION ANGLE (MILLIRADIAN)^2
m6 (100, −)
m1 (200, +)

Figure 6

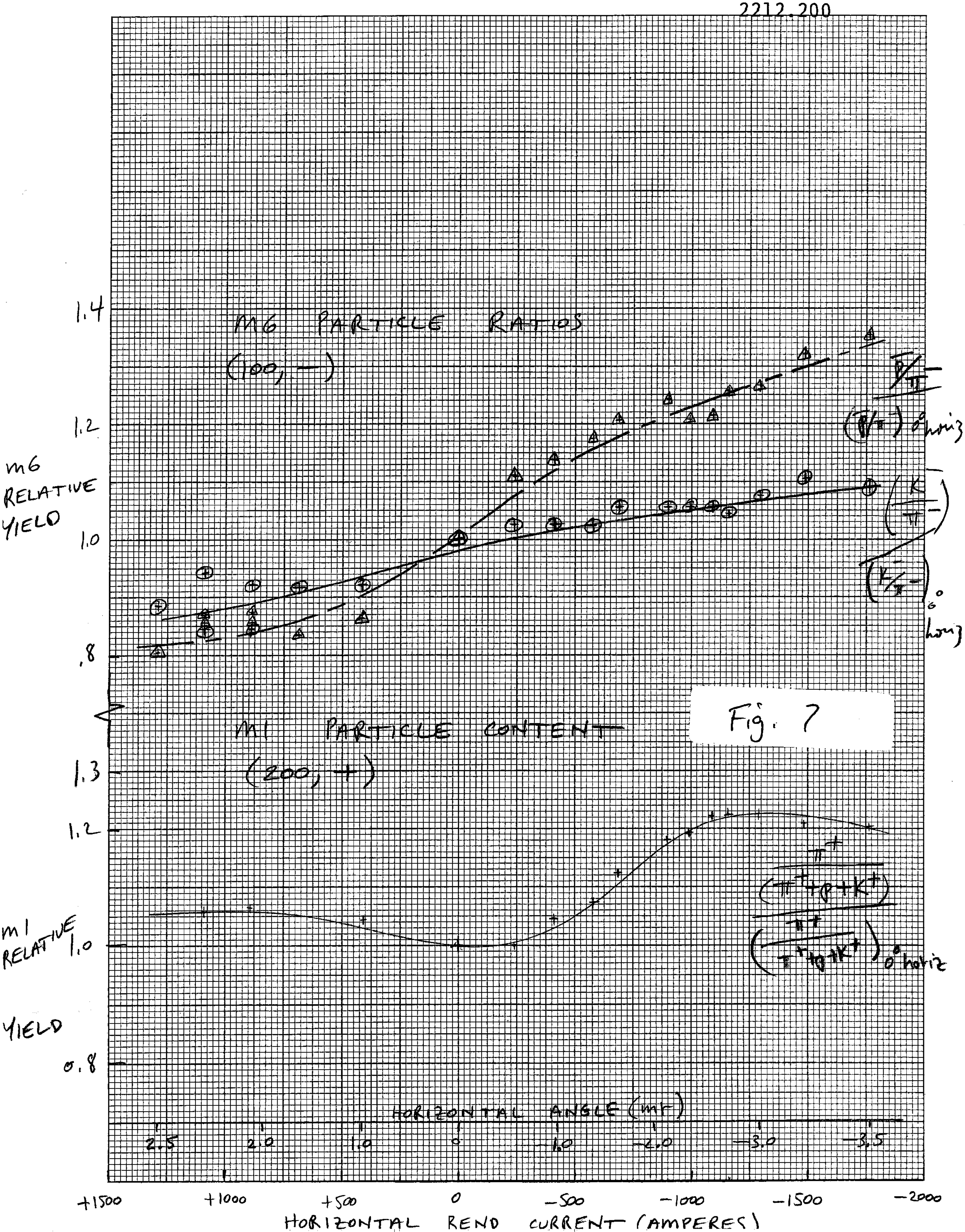
M6 PARTICLE RATIOS
(100, −)
M6 RELATIVE YIELD
1.4
1.2
1.0
.8
$\bar{p}/\pi^-$
$(\bar{p}/\pi^-)_{0°\ horiz}$
K^-/π^-
$(K^-/\pi^-)_{0°\ horiz}$
M1 PARTICLE CONTENT
(200, +)
M1 RELATIVE YIELD
1.3
1.2
1.0
0.8
$\frac{\pi^+}{(\pi^+ + p + K^+)}$
$\left(\frac{\pi^+}{\pi^+ + p + K^+}\right)_{0°\ horiz}$
HORIZONTAL ANGLE (mr)
2.5
2.0
1.0
0
-1.0
-2.0
-3.0
-3.5
+1500
+1000
+500
0
-500
-1000
-1500
-2000
HORIZONTAL BEND CURRENT (AMPERES)

Fig. 7